

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application:

LISTING OF CLAIMS:

1. (original): A spindle apparatus comprising:

an outer cylinder having a stator;

a rotatable rotating shaft having a rotor;

a front side bearing having an outer ring fixed to a front housing and an inner ring fitted over one end of the rotating shaft;

a bearing sleeve disposed on another end side of the rotating shaft and fitted in the outer cylinder so as to be movable in an axial direction of the rotating shaft; and

a rear side bearing having an inner ring fitted over the other end of the rotating shaft and an outer ring fixed to the bearing sleeve to rotatably support the rotating shaft in cooperation with the front side bearing,

wherein the diameter becomes smaller in the order of an inner peripheral diameter of the outer cylinder, an inside diameter of the stator, and an outside diameter of the bearing sleeve, a sub-assembly made up of the front housing, the rotating shaft, and the bearing sleeve is withdrawable from the outer cylinder, and a radius of a rotating part in an arbitrary section located rearwardly of the bearing sleeve is smaller than a minimum radius of a non-rotating part between a rear end of the bearing sleeve and the section.

2. (original): A spindle apparatus comprising:

an outer cylinder having a stator;

a rotatable rotating shaft having a rotor;

a front side bearing having an outer ring fixed to a front housing and an inner ring fitted over one end of the rotating shaft;

a bearing sleeve disposed on another end side of the rotating shaft and fitted in the outer cylinder so as to be movable in an axial direction of the rotating shaft; and

a rear side bearing having an inner ring fitted over the other end of the rotating shaft and an outer ring fixed to the bearing sleeve to rotatably support the rotating shaft in cooperation with the front side bearing,

wherein a sub-assembly made up of the front housing, the rotating shaft, and the bearing sleeve is withdrawable from the outer cylinder, and

an inside diameter part capable of replacing a tool is incorporated in the rotating shaft, and a piston mechanism for tool replacement is provided.

3. (original): The spindle apparatus according to claim 2, wherein

a distance between a mounting reference plane of the sub-assembly and a piston pressing surface of the inside diameter part is adjusted to within ± 0.1 mm relative to a reference dimension.

4. (original): The spindle apparatus according to claim 2, wherein

the inside diameter part is incorporated in such a manner as to be capable of compressing a spring, and an adjustment part is fixed to a rear portion of the inside diameter part, the piston pressing surface for pressing the piston mechanism being formed on the adjustment part.

5. (currently amended): The spindle apparatus according to claim 1 any one of claims 1 to 4, wherein

the front housing is fitted to the outer cylinder with an interference fit.

6. (currently amended): The spindle apparatus according to claim 1 any one of claims 1 to 5, wherein

the bearing sleeve is fitted in a sleeve housing, and
an outside diameter of the bearing sleeve is clearance-fitted with respect to an inside diameter of the sleeve housing.

7. (original): The spindle apparatus according to claim 6, wherein
a plurality of pairs of O-rings are interposed between the outside diameter of the bearing sleeve and the inside diameter of the sleeve housing.

8. (currently amended): The spindle apparatus according to claim 1 any one of claims 1 to 7, wherein

a ratio between a fitting length of the bearing sleeve and the sleeve housing, and an outside diameter of the bearing sleeve is set within a range of fitting length / outside diameter = 0.45 to 0.8.

9. (currently amended): The spindle apparatus according to claim 1 any one of claims 1 to 8, wherein

there are provided a plurality of lubricant discharging holes provided circumferentially in the bearing sleeve, circumferential grooves provided in a fitting surface of an outer periphery of the bearing sleeve, and radial lubricant supplying passages communicatingly connected to the circumferential grooves.

10. (currently amended): The spindle apparatus according to claim 1~~any one of claims 1 to 9~~, wherein

the rear side bearing is a back-to-back arrangement angular contact ball bearing with fixed-position preload.

11. (currently amended): The spindle apparatus according to claim 1~~any one of claims 1 to 10~~, wherein

grease lubrication is adopted.

12. (currently amended): The spindle apparatus according to claim 1~~any one of claims 1 to 11~~, further comprising:

a grease replenishing unit.

13. (currently amended): The spindle apparatus according to claim 1~~any one of claims 1 to 10~~, wherein

a mechanism is provided for discharging excess grease after the supply of grease.

14. (currently amended): The spindle apparatus according to ~~claim 1 any one of claims 1 to 10~~, wherein

a very small amount of lubrication of any one of oil-air, oil-mist, and direct-injection lubrication is used.

15. (original): A spindle apparatus comprising:

a rotatable rotating shaft having a rotor;

a front side bearing having an outer ring fixed to a front housing and an inner ring fitted over one end of the rotating shaft;

a bearing sleeve disposed on another end side of the rotating shaft and fitted in a sleeve housing so as to be movable in an axial direction of the rotating shaft; and

a rear side bearing having an inner ring fitted over the other end of the rotating shaft and an outer ring fixed to the bearing sleeve to rotatably support the rotating shaft in cooperation with the front side bearing,

the spindle apparatus being capable of displacing the other end of the rotating shaft in the axial direction, wherein

an elastic body for sealing the sleeve housing and the bearing sleeve is provided between fitting surfaces of the sleeve housing and the bearing sleeve, and

a fluid for applying pressure is arranged to be supplied to the elastic body.

16. (original): The spindle apparatus according to claim 15, wherein

the elastic body is an O-ring,

the fluid is compressed air, and

the compressed air is supplied between the O-rings provided in a plural number, so as to apply the pressure to the O-rings.

17. (currently amended): The spindle apparatus according to claim 15-~~or~~-16, wherein the pressure of the fluid for applying pressure to the elastic body is variable.

18. (currently amended): The spindle apparatus according to claim 16-~~or~~-17, wherein the O-ring is formed of nitrile rubber or fluoro rubber, and the interference when the O-ring is installed between the sleeve housing and the bearing sleeve is not less than 10% of a working standard value and not more than the working standard value.

19. (currently amended): The spindle apparatus according to claim 15any one of claims 15 to 18, wherein

a plurality of sets of elastic bodies are disposed as the elastic body, each of the sets being formed by a plurality of elastic bodies, one of the sets of elastic bodies arranged at both ends being disposed on the bearing sleeve, another one of the sets of elastic bodies being disposed on the sleeve housing.

20. (original): A machine tool comprising:
a spindle cartridge including a rotatable rotating shaft, a front side bearing having an inner ring fitted over one end of the rotating shaft,
a front housing in which an outer ring of the front side bearing is fitted,

a rotor of a built-in motor, a stator of the built-in motor,
a rear side bearing having an inner ring in which a rear end of the rotating shaft is fitted,
and
an outer cylinder fitted in a spindle head,
wherein the spindle cartridge is inserted in a spindle cartridge gripping portion provided
in an axial direction of the spindle head, and
an amount of movement in a feeding axis direction parallel to an axial direction of the
rotating shaft is set to be longer than a length necessary for inserting the spindle cartridge into
the spindle head,
the spindle cartridge is capable of being disassembled and assembled integrally with
respect to the spindle head.

21. (original): A machine tool comprising:
a spindle sub-cartridge including a rotatable rotating shaft,
a front side bearing having an inner ring fitted over one end of the rotating shaft,
a front housing in which an outer ring of the front side bearing is fitted,
a rotor of a built-in motor,
a stator of the built-in motor,
a rear side bearing having an inner ring in which a rear end of the rotating shaft is fitted,
and
a bearing sleeve in which an outer ring of the rear side bearing is fitted,

wherein an amount of movement in a feeding axis direction parallel to an axial direction of the rotating shaft is set to be longer than a length necessary for inserting the spindle sub-cartridge into the spindle head,

the spindle sub-cartridge is capable of being disassembled and assembled integrally with respect to the spindle head.

22. The machine tool according to claim 20-~~or 21~~, wherein the spindle cartridge gripping portion of the spindle head can be disassembled by being divided at a position for dividing at least in half.

23. (original): A spindle apparatus comprising:
an outer cylinder having a stator;
a spindle head in which the outer cylinder is fitted;
a rotatable rotating shaft with a rotor disposed inside the stator;
a front side bearing having an inner ring in which one end of the rotating shaft is fitted;
a rear side bearing having an inner ring in which another end of the rotating shaft is fitted;
a front housing in which an outer ring of the front side bearing is fitted and which is installed at one end of the outer cylinder;
a sleeve housing in which an outer ring of the rear side bearing is fitted and which is fitted in another end of the outer cylinder; and
a tool unclamp cylinder fixed to one end of the outer cylinder,
wherein

the rotating shaft with the rotor, the front side bearing, the rear side bearing, the front housing, and the sleeve housing are integrally assembled to form a spindle sub-cartridge, the spindle sub-cartridge, the outer cylinder, and the tool unclamp cylinder are arranged in a three-divided form, and the spindle sub-cartridge is withdrawable from the outer cylinder.

24. (original): The spindle apparatus according to claim 23, wherein the tool unclamp cylinder is withdrawable from the outer cylinder.

25. (original): The spindle apparatus according to claim 24, wherein an assembly of the tool unclamp cylinder and the outer cylinder with the spindle sub-cartridge withdrawn therefrom is withdrawable from the spindle head.

26. (currently amended): The spindle apparatus according to claim 23~~any one of claims 23 to 25~~, wherein an assembly of the spindle sub-cartridge, the outer cylinder, and the tool unclamp cylinder is withdrawable from the spindle head.

27. (currently amended): The spindle apparatus according to claim 23~~any one of claims 23 to 26~~, wherein a coupler having various fluid pipings and a power supply coupler is detachably installed on the tool unclamp cylinder or the outer cylinder.

28. (currently amended): The spindle apparatus according to claim 23 any one of claims 23 to 27, wherein

a sensor for detecting the rotation of the rotating shaft is disposed between the rotating shaft and the outer cylinder.

29. (new): The spindle apparatus according to claim 2, wherein the front housing is fitted to the outer cylinder with an interference fit.

30. (new): The spindle apparatus according to claim 2, wherein the bearing sleeve is fitted in a sleeve housing, and an outside diameter of the bearing sleeve is clearance-fitted with respect to an inside diameter of the sleeve housing.

31. (new): The spindle apparatus according to claim 6, wherein a plurality of pairs of O-rings are interposed between the outside diameter of the bearing sleeve and the inside diameter of the sleeve housing.

32. (new): The spindle apparatus according to claim 2, wherein a ratio between a fitting length of the bearing sleeve and the sleeve housing, and an outside diameter of the bearing sleeve is set with a range of fitting length/outside diameter = 1.45 to 0.8.

33. (new): The spindle apparatus according to claim 2, wherein

there are provided a plurality of lubricant discharging holes provided circumferentially in the bearing sleeve, circumferential grooves provided in a fitting surface of an outer periphery of the bearing sleeve, and radial lubricant supplying passages communicatingly connected to the circumferential grooves.

34. (new): The spindle apparatus according to claim 2, wherein the rear side bearing is a back-to-back arrangement angular contact ball bearing with fixed-position preload.

35. (new): The spindle apparatus according to claim 2, wherein grease lubrication is adopted.

36. (new): The spindle apparatus according to claim 2, further comprising: a grease replenishing unit.

37. (new): The spindle apparatus according to claim 2, wherein a mechanism is provided for discharging excess grease after the supply of grease.

38. (new): The spindle apparatus according to claim 2, wherein

a very small amount of lubrication of any one of oil-air, oil-mist, and direct-injection lubrication is used.

39. (new): The spindle apparatus according to claim 17, wherein the O-ring is formed of nitrile rubber or fluoro rubber, and the interference when the O-ring is installed between the sleeve housing and the bearing sleeve is not less than 10% of a working standard value and not more than the working standard value.

40. (new): The spindle apparatus according to claim 21, wherein the spindle cartridge gripping portion of the spindle head can be disassembled by being divided at a position for dividing at least in half.